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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Adaptive forward error control scheme

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DESCRIPTION

Field of the invention

The invention deals with an adaptive Forward Error Correction scheme (FEC) aiming at providing a resilient transport of data over a packet-switched transmission network.

The invention also deals with a transmission system, a transmitter and a receiver implementing such a forward error control scheme.

The invention also deals with a method for determining an amount of redundancy to be used in such a forward error correction scheme.

The invention advantageously applies to the transport of data over a transmission network having a time varying state, for instance over a mobile transmission network.

Background of the invention

The international patent application WO99/04338 describes an adaptive forward error correction scheme to be used for transmission over wireless satellite links.

The forward error correction scheme described in this document operates at the data link level of the OSI reference model (a forward error correction code is included in each frame for error correction of that frame). It includes the steps of: calculating a byte error rate, determining a forward error correction code length based on this byte error rate, and feeding back the forward error correction code length to the transmitter. The value of the forward error correction code length is selected in a table storing inverse byte error rate values in association with forward error correction code lengths.

Because it is implemented at the data link level, the proposed method is not well suited to heterogeneous transmission network like the Internet. Using the described method in a heterogeneous transmission network would lead to a separate adaptation of the forward error correction scheme in each network section that is gone through. This would be very complex to implement.

Further more using a table to determine the error correction code length has several drawbacks.

First, certain assumptions about the repartition and the size of the errors are made in order to derive the values stored in the table. And therefore the proposed method is not well suited to transmission networks which state may vary in an important manner, as to mobile networks like GSM, UMTS, GPRS...

Second, the values stored in the table are derived so as to obtain a certain quality after correction. This means that the receiver must store as many tables as achievable qualities.

Summary of the invention

An object of the invention is to propose an adaptive forward error control scheme that overcomes these drawbacks.

This is achieved with a transmission system as claimed in claims 1 to 3, a receiver as claimed in claims 4 and 5, a transmitter as claimed in claims 6 and 7, a method for determining the amount of redundancy to be used in a forward error control scheme as claimed in claims 8 and 9, and a program as claimed in claim 10.

In the adaptive forward error correction scheme of the invention, redundancy packets are generated at the application layer of transmitter from media packets. Therefore when erroneous packets are discarded by the transport layer at the receiver side, the application layer is capable of recovering a certain number of packets from the packets it receives. According to the invention the amount of redundancy that is added at the transmitter side is adapted so as to obtain a correction capability allowing to respect a maximum tolerated packet error rate. According to the invention, the quality of the transmission network is estimated by watching the packet error rate.

Because it is implemented at the application layer, the method of the invention is transparent to the transmission network. It is therefore easily applicable to heterogeneous transmission network.

Because the quality of the transmission network is estimated by using the packet error rate instead of the byte error rate, the use of tables can be avoided.

The invention guarantees a maximum tolerated packet error from end to end. Advantageously the maximum tolerated packet error rate is set by the application that is using the received media packets.

In an advantageous embodiment of the invention, the bitrate of the media packets is adapted as a function of k so as to compensate for the variations of the bitrate of the redundancy packets.

Brief description of the drawings

These and other aspects of the invention are further described with reference to the following drawings:

- figure 1 is a schematic drawing of a transmission system according to the invention,
- figure 2 is a schematic representation of the generation of a transmission block,
- figure 3 is a schematic representation of the adaptation of the amount of redundancy contained in a transmission block depending on the state of the transmission network,
- figure 4 is a block diagram of a method for determining an amount of redundancy to be used in a forward error correction scheme according to the invention.

Description of a preferred embodiment

The invention applies to any FEC scheme. In the examples described in the following, the FEC code is characterized by two parameters k and n, where k is the number of media packets, and $(n-k)$ is the number of redundancy packets generated from the k media packets.

The parameter n has a constant integer value. The amount of redundancy is adapted by varying the value of the parameter k. This is not restrictive.

Figure 1 shows an example of a transmission system according to the invention comprising a transmitter 1, a transmission network 2 and a receiver 3. In this example the transmission network 2 is composed of the Internet network and of a radio access network (for instance a network compliant with the GPRS or the UMTS standards). The transmitter 1 comprises a media source 10 for delivering media packets, a FEC encoder 12 for generating redundancy packets from media packets received from the media source 10, and a transmission/reception block 14 implementing the first four layers of the OSI reference model. In this example, the network protocol (OSI layer 3) is IP (Internet Protocol) and the transport protocol (OSI layer 4) is RTP (Real time Transfer Protocol) over UDP (User Datagram Protocol). The receiver 3 comprises a transmission / reception block 32 that implements the first four layers of the OSI reference model, an analyser 34, a FEC decoder 36 and an application block 38.

As represented in figure 2, the encoder 12 generates (n-k) redundancy packets $R_1(i)$, ..., $R_{n-k}(i)$ from k media packets $M_1(i)$, ..., $M_k(i)$. The (n-k) redundancy packets and the k media packets form a transmission block TB(i). The redundancy packets are intended to provide a correction capability of Q(k) packets at the receiver.

At the receiver side, the UDP protocol controls the UDP checksum for each received packets. And it discards the packets for which at least one bit error is detected. The packets that are correctly received are forwarded to the FEC decoder 36. The FEC decoder 36 is capable of recovering the discarded packets from the packets that it receives, if the number of discarded packets is smaller or equal to Q(k).

Advantageously the code used to generate the redundancy is a Reed Solomon code RS(n,k). The correction capability of a Reed Solomon code RS(n,k) is Q(k)=n-k.

According to the invention the amount of redundancy is adapted depending on the state of the network so as to use the bandwidth in an optimal way. If the transmission network is in a good state the amount of redundancy shall be decreased so that a larger part of the bandwidth can be dedicated to the transmission of media packets. On the contrary, if the transmission network is in bad state the amount of redundancy shall be increased so as to higher the chances of recovering discarded media packets at the receiver side.

Advantageously k shall not be smaller than a minimum value k_{min} corresponding to a maximum tolerated amount of redundancy.

An example of such an adaptation is represented schematically in figure 3. The curve S gives the evolution of the state S(t) of the transmission network as a function of time t. The mark G on the Y-axis indicates a good state. The mark D on the Y-axis indicates a bad state. The composition of the transmission blocks TB(i) is indicated in relation with the curve S. It can be seen that the number k_i of media packets transmitted in the transmission block TB(i) is higher when the state of the network is better.

The adaptation of the amount of redundancy contained in the transmission blocks TB(i) is controlled by the analyser 34. The analyser 34 analyses the packet errors occurring on the transmission network and generates orders 42 for the FEC encoder 12. The orders 42 contain an optimal value $k_{optimal}$ to be used by the FEC encoder 12. They are transmitted to the transmitter 1 using RTCP feedback messages.

The operations of the analyser 34 will now be described in more details with reference to figure 4.

For computing $k_{optimal}$, the analyser 34 keeps an historic of the number P_i of packet errors in the received transmission blocks TB(i). Preferably, the size of this historic corresponds to several Round Trip Time through the transmission network. The number of packet errors in a transmission block TB(i) is equal to the number of lost packets. Packet losses are detected by using the RTP sequence numbers (the header of the RTP packet contains a sequence number; the value of the sequence number is incremented by one each time a packet is transmitted; at the receiver missing sequence numbers correspond to lost packets).

When the analyser 34 detects the end of a transmission block TB(i) (box T1 in figure 4), it calculates and stores the number P_i of packet errors in this transmission block (box T2). Then the analyser 34 executes the following operations for k varying from n to k_{min}.

- The analyser estimates the capability correction Q(k) (box T4).
- Given the number P_i of packet errors and the correction capability Q(k), the analyser 34 computes the number $P_i'(k)$ of packet errors after correction (box T5):

$$\begin{cases} P_i'(k) = 0 & \text{if } 0 \le P_i \le Q(k) \\ P_i'(k) = P_i & \text{if } Q(k) < P_i \le n \end{cases}$$

- The analyser 34 calculates a mean value M(k) of the number $P_i'(k)$ of packet errors after correction (box T6). Advantageously more importance is given to the last packet errors when calculating the mean value M(k) because they are more meaningful for the knowledge of the current network state. This allows to react faster to the variations of the transmission network. For instance:

$$M(k) = \frac{\sum_{i=1}^{m} \omega_i P_i'(k)}{\sum_{i=1}^{m} \omega_i}$$

where m is the number of transmission blocks in the historic and:

$$\begin{cases} \omega_i = 1 & \text{for } 1 \le i \le m/2 \\ \omega_i = 1 - \dfrac{i - m/2}{m/2+1} & \text{for } m/2 < i \le m \end{cases}$$

- The corresponding packet error rate $R(k)=M(k)/n$ is compared with a maximum tolerated packet error rate PER_{MAX} (box T7). If $R(k) \le PER_{MAX}$ or if $k = k_{min}$, then $k_{optimal}$ is set to the current value of k ($k_{optimal}$=k) and it is sent in a feedback message to the FEC encoder 12 (box T8). In the other cases, k is decreased by one (box T9) and the above-mentioned operations are executed for the new value of k.

In a preferred embodiment, the maximum tolerated packet error rate is set by the application block 38 (arrow 39 in figure 1). Thus different applications can set different maximum tolerated packet error rates.

The optimal value of k is the highest value of k allowing to respect the maximum tolerated packet error rate PER_{MAX} after correction.

Alternatively the new value of $k_{optimal}$ is fed back to the transmitter only when it differs from the previous one.

Advantageously, the media source 10 is delivering media packets with an adaptable bitrate, called media bitrate, and the media source 10 is controlled by the FEC encoder 12 in order to adapt the media bitrate as a function of k with the aim of compensating for the variation of the redundancy bitrate. In a first embodiment, the media source is a real time encoder which encoding bitrate is changed on the fly under reception of an order from the FEC encoder. In a second embodiment the media source 10 comprises a file switcher intended to switch between several pre-encoded files, each pre-encoded file corresponding to a specific media bitrate. For applications operating at a constant bitrate CB, the media bitrates MB(k) of the pre-encoded files are advantageously chosen as follows:

$$MB(k) = \frac{k}{n} CB \text{ for } k_{min} \le k \le n .$$

In another embodiment (not represented here) the transmitter comprises a rate control block intended for estimating the current channel bitrate and for controlling the media source 10. In this embodiment, the media source adapts the media bitrate depending on k and depending on an order received from the rate control block so that the overall bitrate (equal to the sum of the media bitrate and the redundancy bitrate) matches the current channel bitrate.

The functions of the analyser 34 that have just been described are implemented in software on a processor of the receiver 3.

With respect to the described system, transmitter, receiver and method of determining the amount of redundancy to be added to the media, modifications or improvements may be proposed without departing from the scope of the invention. The invention is thus not limited to the examples provided.

In particular the media packets and their corresponding redundancy packets are not necessarily transmitted in transmission blocks of constant size.

The order fed back by the receiver is not necessarily the optimal value of k. It could be any indication of the optimal amount of redundancy to add to the media (for instance it could be the

optimal value of (n-k) or the optimal value of the overhead, the overhead being classically defined as $100 \times \frac{(n-k)}{k} \%$).

The invention is not restricted to the use of Reed Solomon codes. Any correctioncode which correction capacity is a function of k and n can be used.

The word "comprising" does not exclude the presence of other elements or steps than those listed in the claims.

CLAIMS

1. A transmission system comprising at least a transmitter, a transmission network having a time varying state, and a receiver, said transmitter comprising an encoder for generating redundancy packets (R(I)) from media packets (M(i)) so as to provide an error correction capability of a certain number of packets (Q(k)) at said receiver, said correction capability depending on the amount of redundancy (n-k) generated by said encoder, said receiver comprising an analyser for analysing the packet errors occurring on the transmission network, and for computing an optimal amount of redundancy that gives an error correction capability allowing to respect a maximum tolerated packet error rate (PER_{MAX}), said optimal amount of redundancy being fed back to said transmitter so as to be used by said encoder.

2. A transmission system as claimed in claim 1, wherein said transmitter comprises a media source for delivering said media packets with an adaptable media bitrate and said encoder is designed so as to send to said media source an order for adapting said media bitrate depending on the amount of redundancy currently added by the encoder.

3. A transmission system as claimed in claim 1, wherein (n-k) redundancy packets are generated from k media packets so as to form a transmission block of n packets, and said analyser is designed so as to:

a) keep an historic of the number B_i of packet errors in a transmission block,

b) and for different value of k:

- calculate a mean value C(k) of the number $C_i(k)$ of packet errors in a transmission block after correction with an error correction capability of Q(k),
- calculate the corresponding packet error rate (C(k)/n),
- compare the corresponding packet error rate with said maximum tolerated packet error rate (PER_{MAX}) for selecting said optimal value of k.

4. A receiver for receiving media packets and redundancy packets transmitted by a transmitter over a transmission network having a time varying state, said redundancy packets being generated from said media packets so as to provide an error correction capability of a certain number of packets at said receiver, said correction capability depending on the amount of redundancy generated at the transmitter, said receiver comprising:

- an analyser for analysing the packet errors occurring on the transmission network and for computing an optimal amount of redundancy that gives an error correction capability allowing to respect a maximum tolerated packet error rate (PER_{MAX}),
- and feedback means for feeding back said optimal amount of redundancy to said transmitter.

5. A receiver as claimed in claim 4, intended for receiving transmission blocks of n packets comprising k media packets and (n-k) redundancy packets generated from said k media packets, wherein said analyser is designed so as to:

a) keep an historic of the number B_i of packet errors in a transmission block,

b) and for different value of k:

- calculate a mean value C(k) of the number $C_i(k)$ of packet errors in a transmission block after correction with an error correction capability of Q(k),
- calculate the corresponding packet error rate (C(k)/n),
- compare the corresponding packet error rate with said maximum tolerated packet error rate (PER_{MAX}) for selecting said optimal value of k.

6. A receiver as claimed in claim 4, wherein the received media packets being intended to be used by an application, said maximum tolerated packet error rate is set by said application.

7. A transmitter for transmitting packets to a receiver over a transmission network having a time varying state, said transmitter comprising an encoder for generating redundancy packets from media packets so as to provide an error correction capability of a certain number of packets at the receiver, said correction capability depending on the amount of redundancy generated by said encoder, and said encoder being designed for setting said amount of redundancy to an optimal value that gives an error correction capability allowing to respect a maximum tolerated packet error rate defined at the receiver, said optimal value being fed back to said transmitter by said receiver.

8. A transmitter as claimed in claim 7, comprising a media source for delivering said media packets with an adaptable media bitrate and wherein said encoder is designed so as send to said media source an order for adapting said media bitrate depending on the amount of redundancy currently added by the encoder.

9. A method for determining an amount of redundancy to be used in a forward error correction scheme in which redundancy packets are generated from media packets at a transmitter side, so as to provide a correction capability of a certain number of packets at a receiver side, said method comprising the steps of:

- analysing the packet errors occurring on the transmission network, at he receiver side,
- computing an optimal amount of redundancy that gives an error correction capability allowing to respect a maximum tolerated packet error rate, at the receiver side,
- feeding back said optimal amount of redundancy to the transmitter.

10. A program comprising instructions for implementing a method as claimed in claim 9 when said program is executed by a processor.

ABSTRACT

ADAPTATIVE FORWARD ERROR CONTROL SCHEME

The invention applies to packets transmission networks. It proposes an adaptive forward error control scheme implemented at the application level, allowing to respect a maximum tolerated packet error rate. According to the invention the amount of redundancy is adapted so as to offer a correction capability allowing to respect said maximum tolerated packet error rate.

Advantageously the maximum tolerated packet error rate is set by the application.

Application: transmission over networks having a time-varying state, notably mobile networks.

Reference: figure 1.

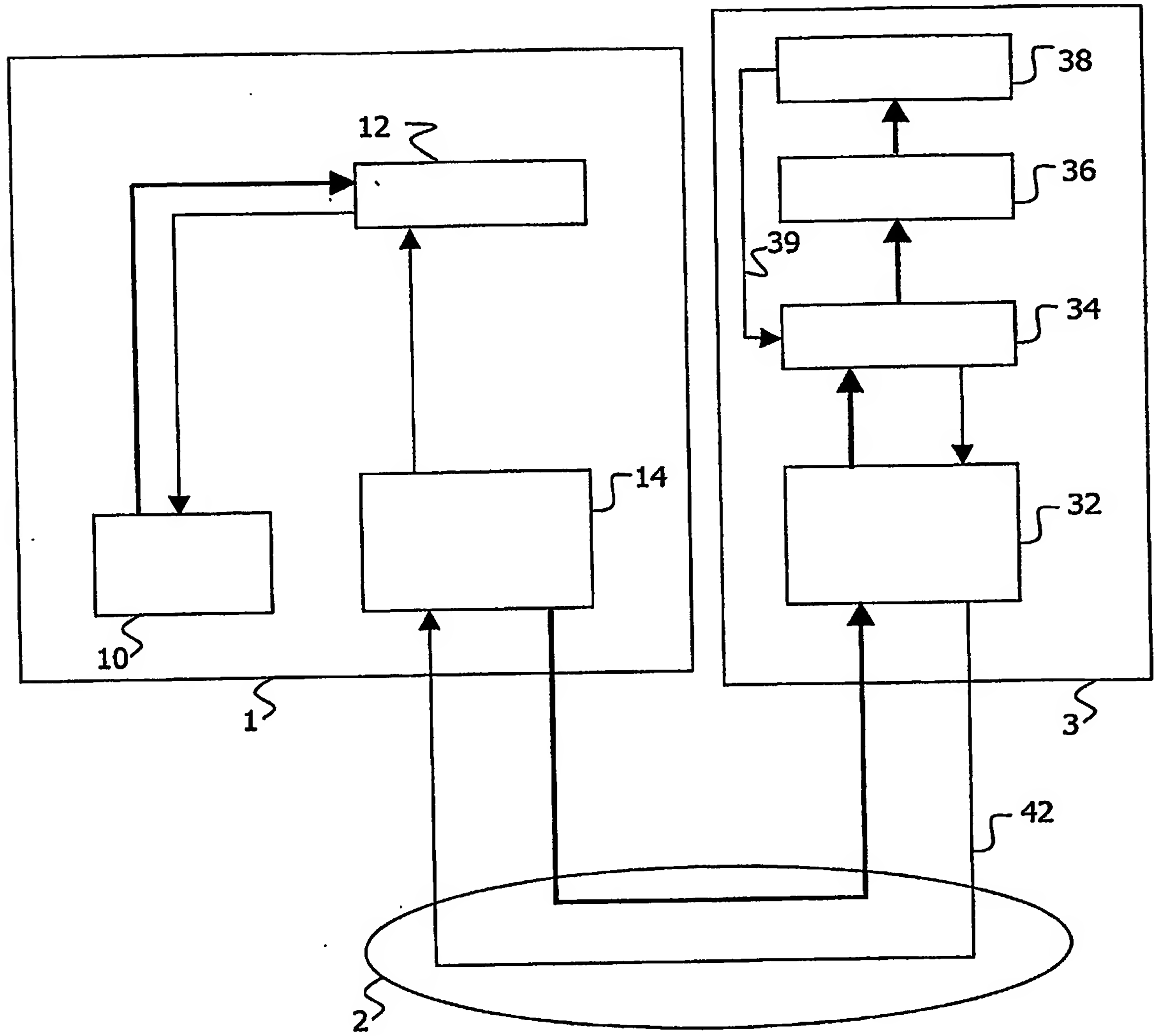
12
14
10
1
38
36
39
34
32
3
42
2

FIG.1

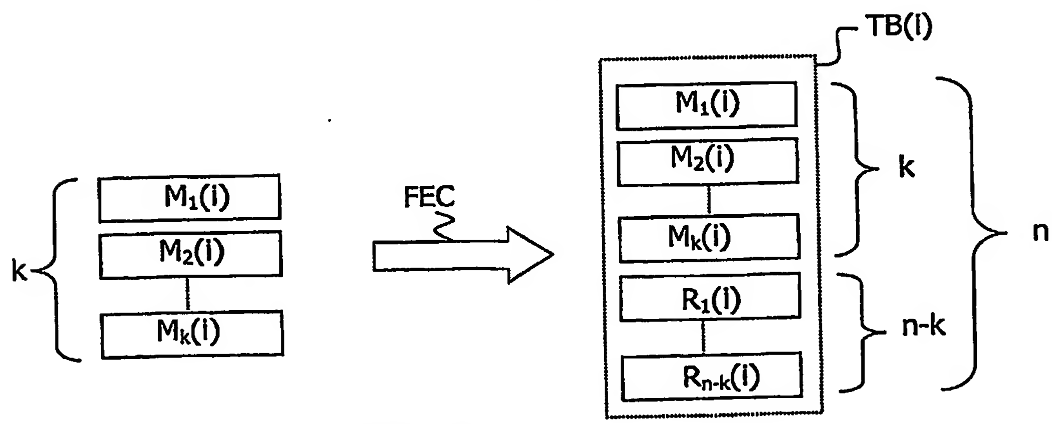
k
$M_1(i)$
$M_2(i)$
$M_k(i)$
FEC
TB(i)
$M_1(i)$
$M_2(i)$
$M_k(i)$
$R_1(i)$
$R_{n-k}(i)$
k
n-k
n

FIG.2

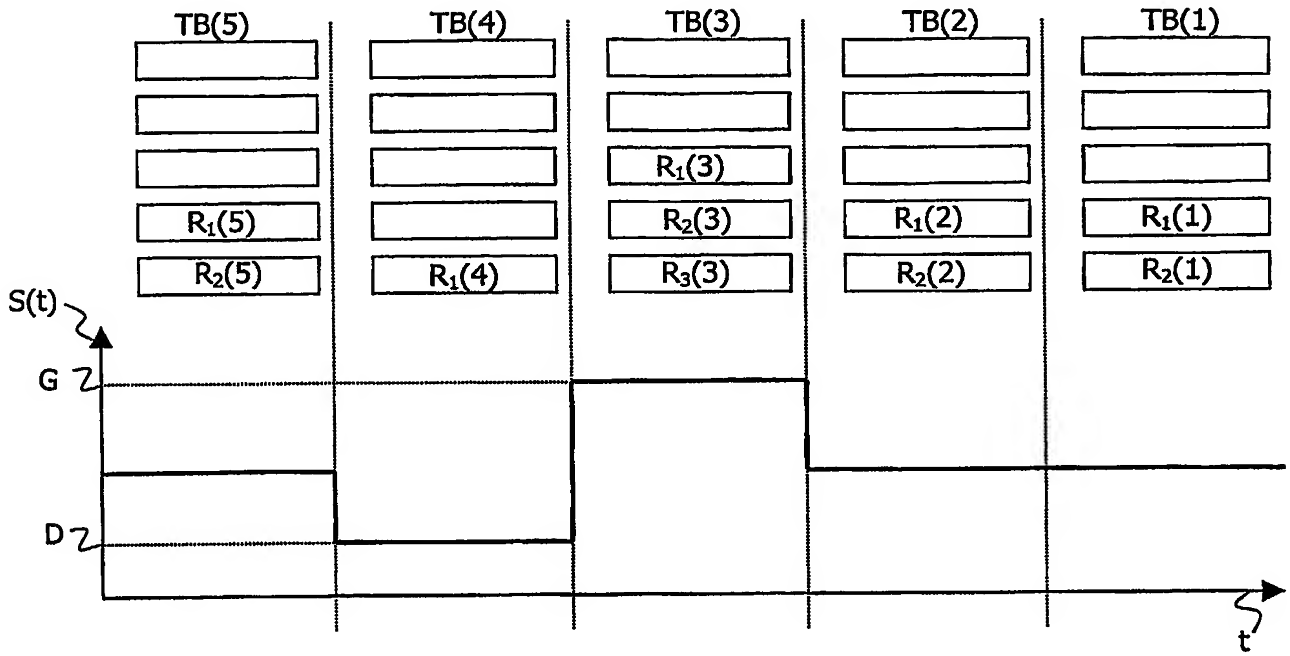
TB(5)
TB(4)
TB(3)
TB(2)
TB(1)
R1(5)
R2(5)
R1(4)
R1(3)
R2(3)
R3(3)
R1(2)
R2(2)
R1(1)
R2(1)
S(t)
G
D
t

FIG.3

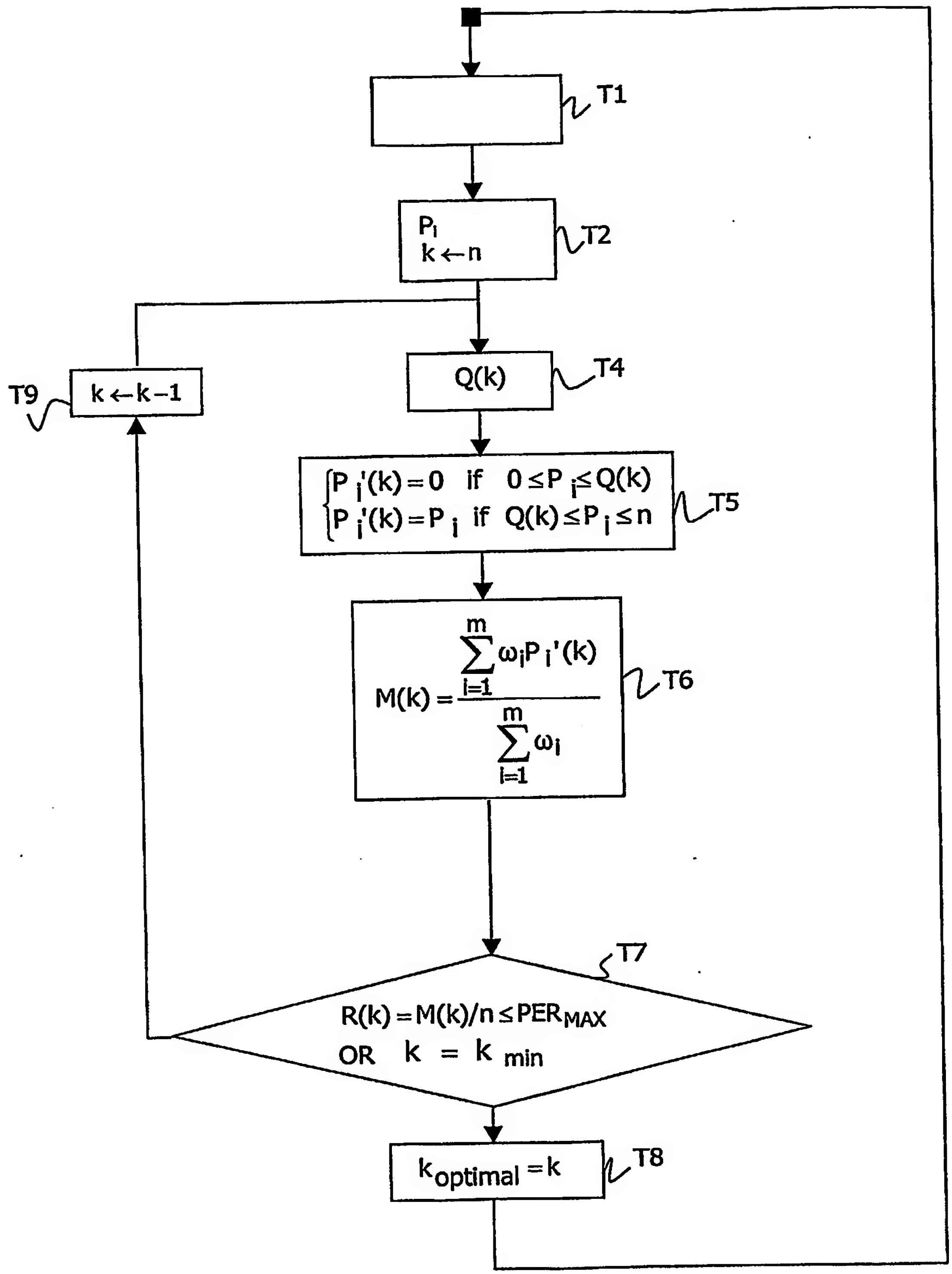
T1
P_i
$k \leftarrow n$
T2
Q(k)
T4
$k \leftarrow k-1$
T9
$\begin{cases} P_i'(k) = 0 & \text{if } 0 \le P_i \le Q(k) \\ P_i'(k) = P_i & \text{if } Q(k) \le P_i \le n \end{cases}$
T5
$M(k) = \frac{\sum_{i=1}^{m} \omega_i P_i'(k)}{\sum_{i=1}^{m} \omega_i}$
T6
T7
$R(k) = M(k)/n \le PER_{MAX}$
OR $k = k_{min}$
$k_{optimal} = k$
T8

FIG.4